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AIRS and Aqua Mission Operations Status and New AIRS On-board Gain Table

Denis Elliott

November 11, 2011

Outline

- AIRS operations status
- AMSU-A operations status
- Aqua spacecraft status
- Other Aqua instruments status
- New AIRS gain table

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AIRS Operations Status

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AIRS Operational Status

- **AIRS is in excellent health**
- **All engineering parameter plots versus time are either flat or changing extremely slowly—no concerns**
- **Some channels have degraded noise performance due to radiation dosage**
  - ***Many of the degraded channels can have their noise performance significantly improved by revising the on-board gain table***
  - ***Details later in this presentation***

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AIRS Chopper Drive Current

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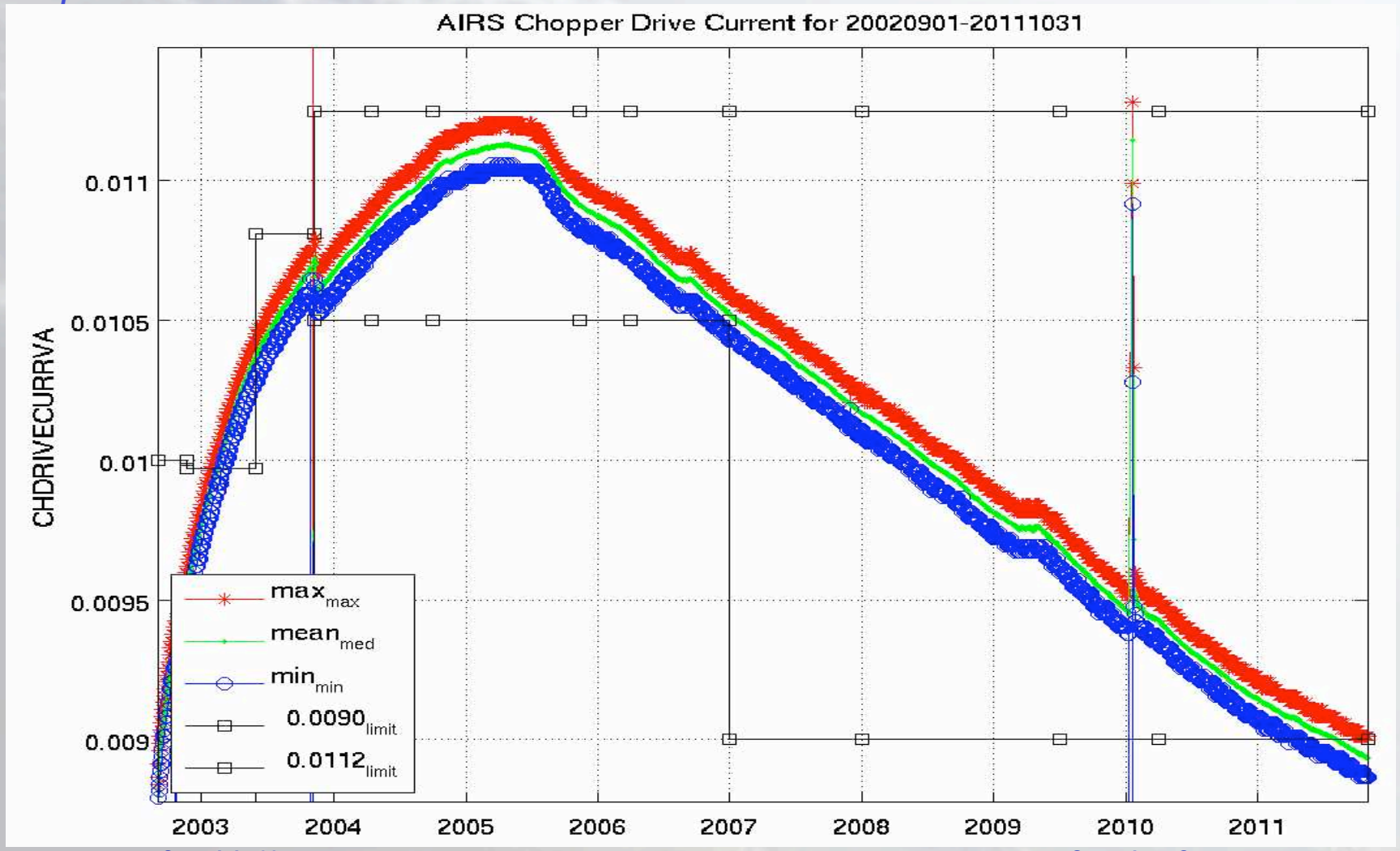

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AIRS Scan Mirror Temperature

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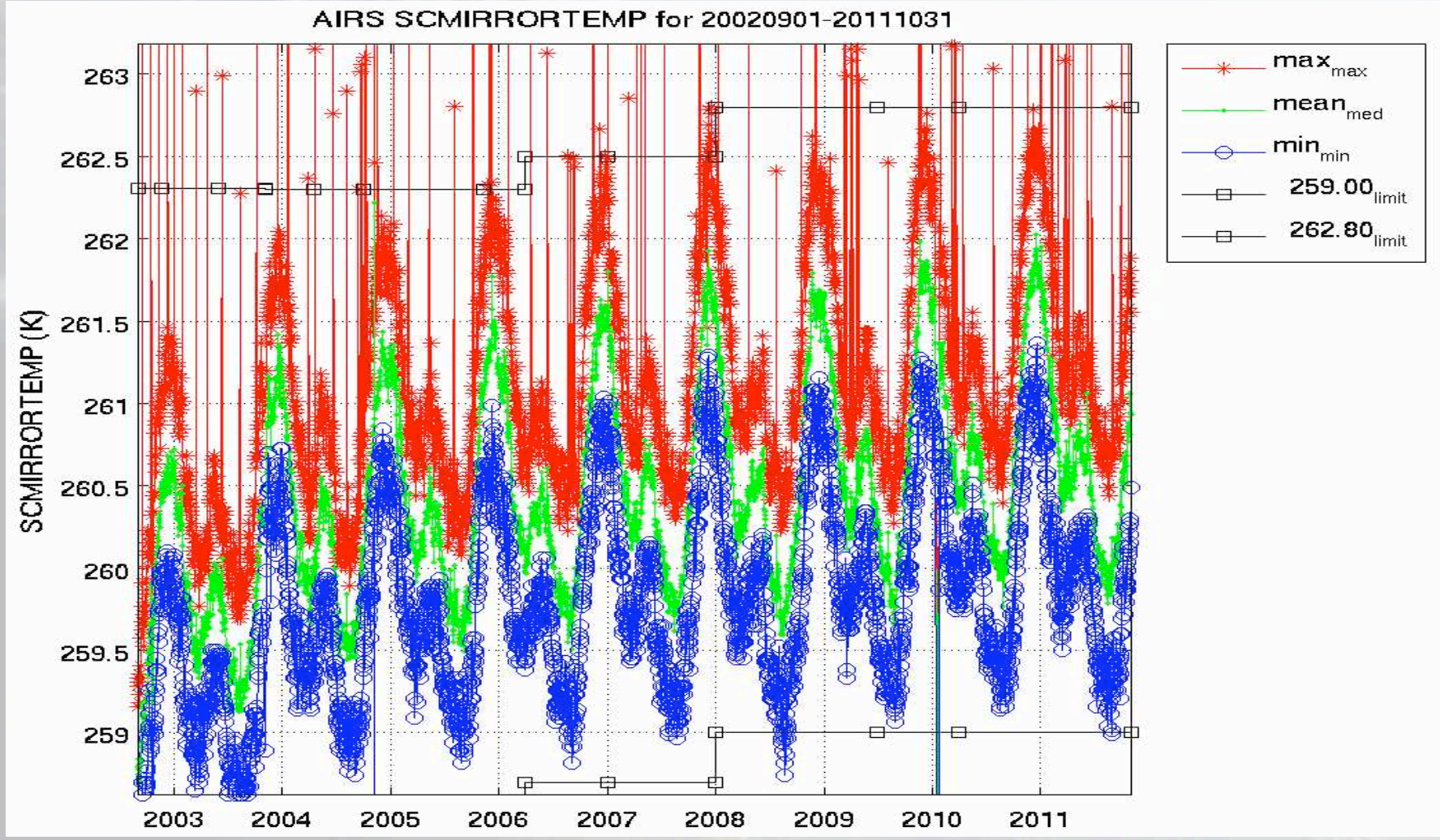

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AIRS Choke Point Heater Current

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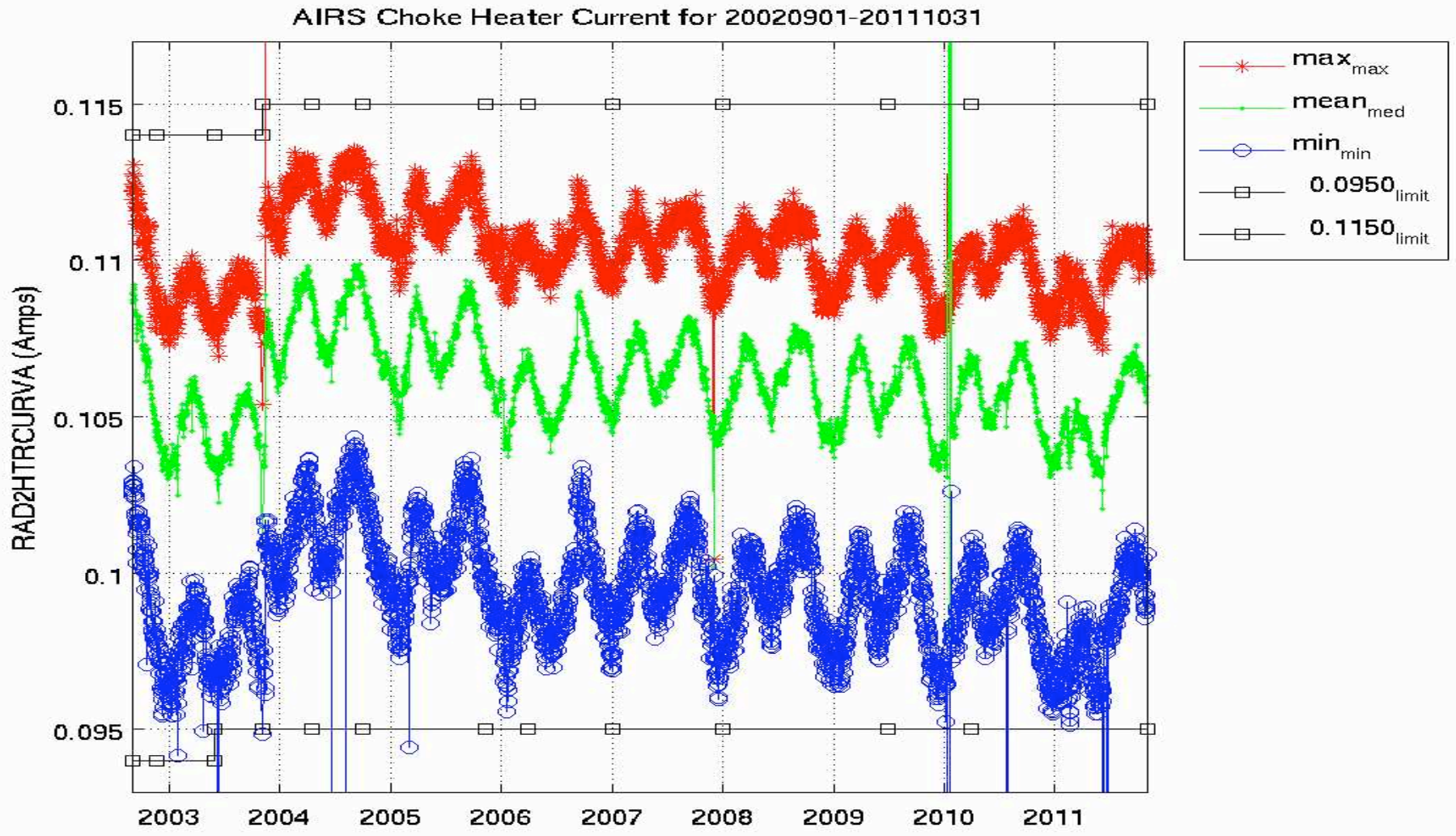

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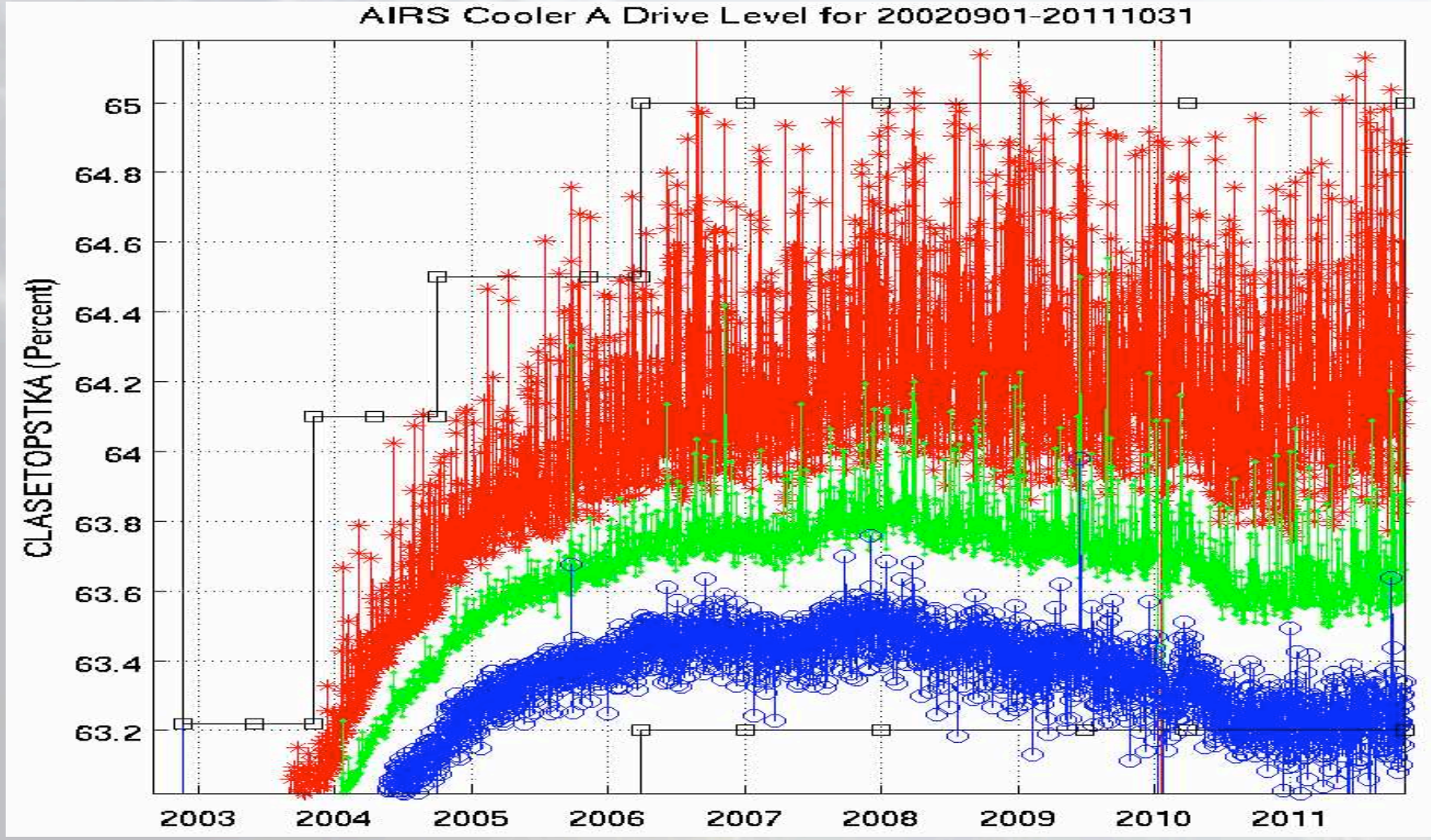
AIRS Cooler A Drive Level



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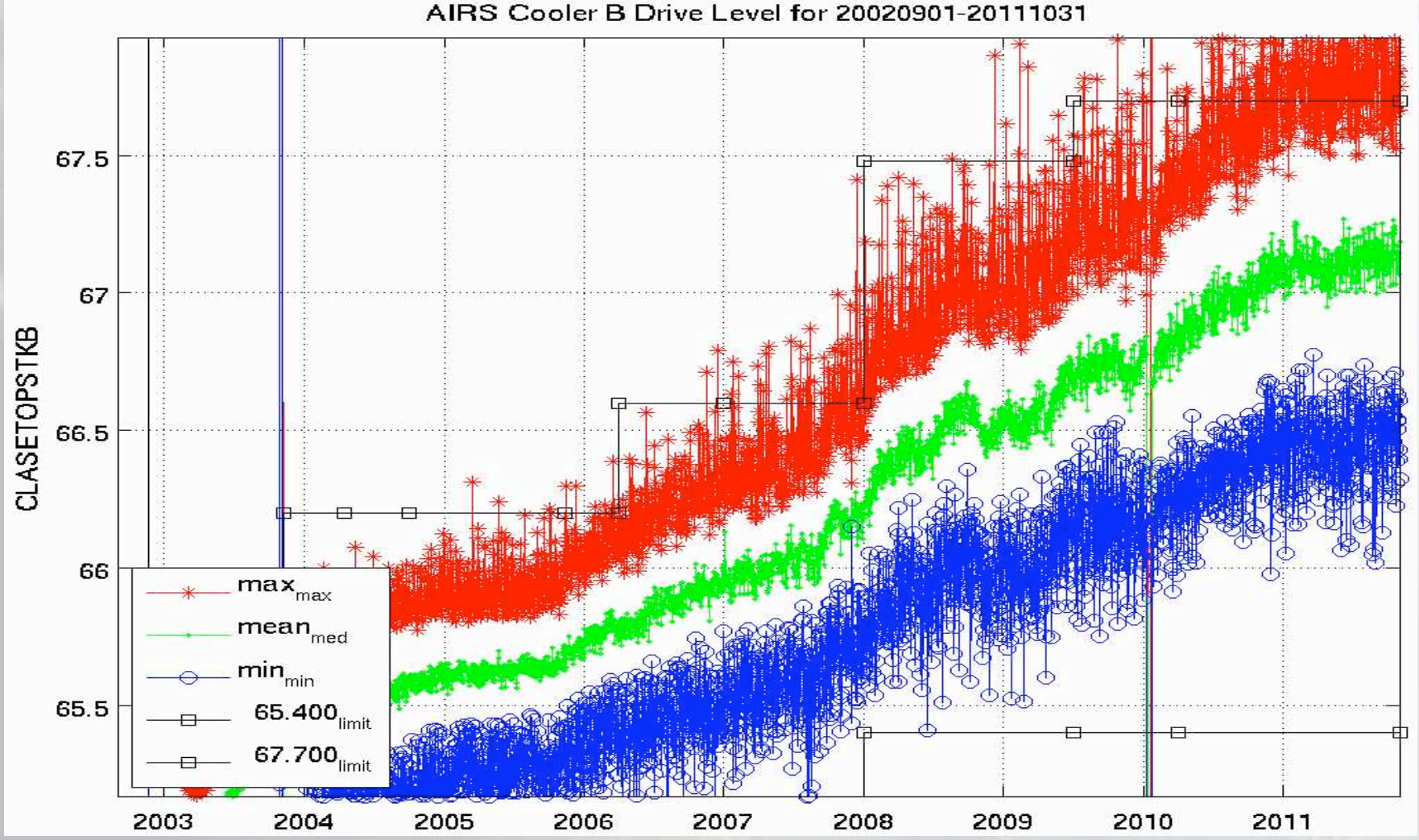
AIRS Cooler B Drive Level



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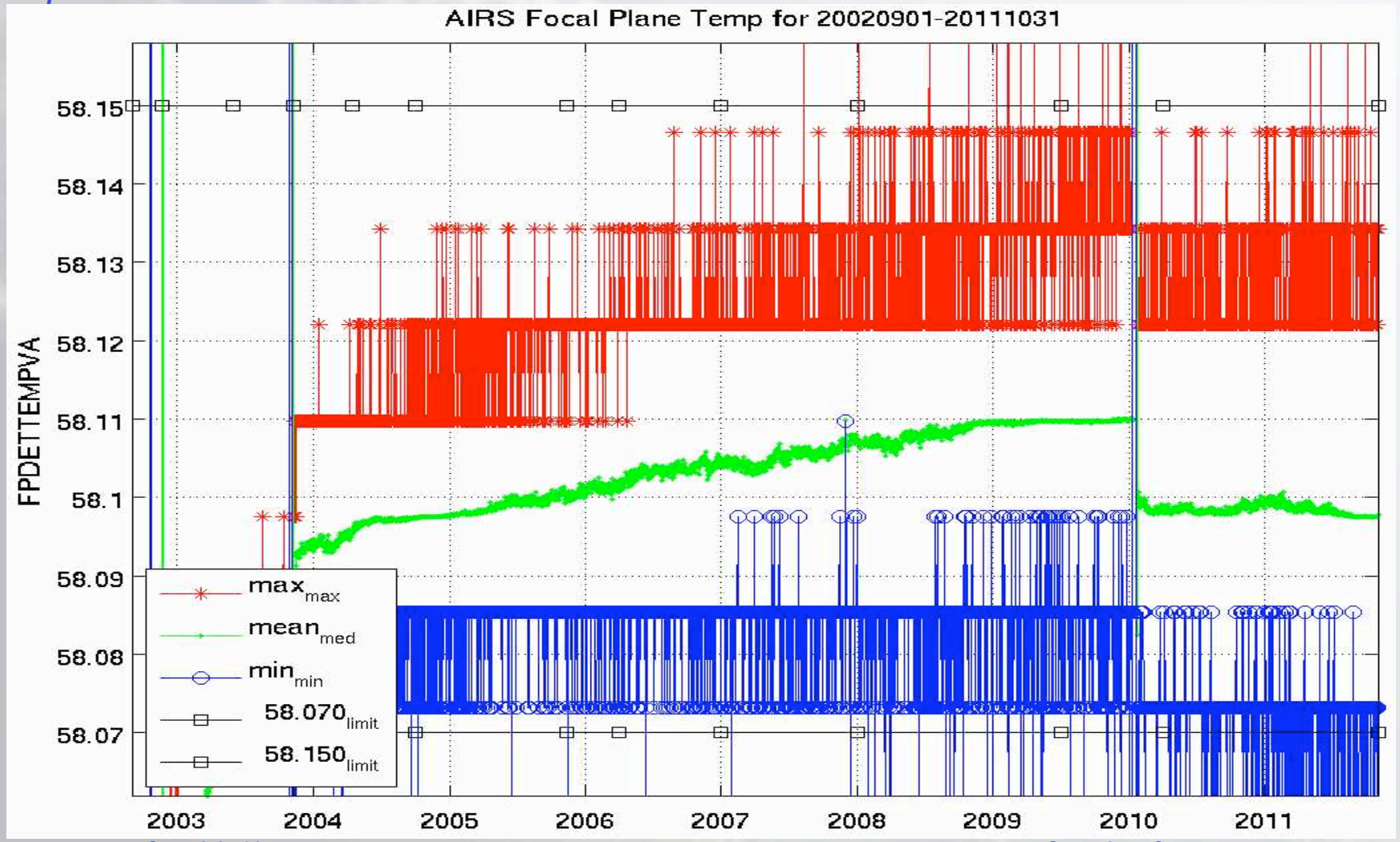
AIRS Focal Plane Temperature

Atmospheric Infrared Sounder



AMSU-A Status

AMSU-A Operational Status

- **AMSU-A mechanical parts and most of the electronics are in very good health**
- **Engineering parameter trends are slow—no concerns**
- **12 of the 15 channels are rock solid, but**
  - ***Channel 4 failed in 2007 (declared non-operational on October 1 2007)***
  - ***Channel 5 continues to degrade***
  - ***Channel 7 noise has exceeded specs since launch and has never been used for L2***

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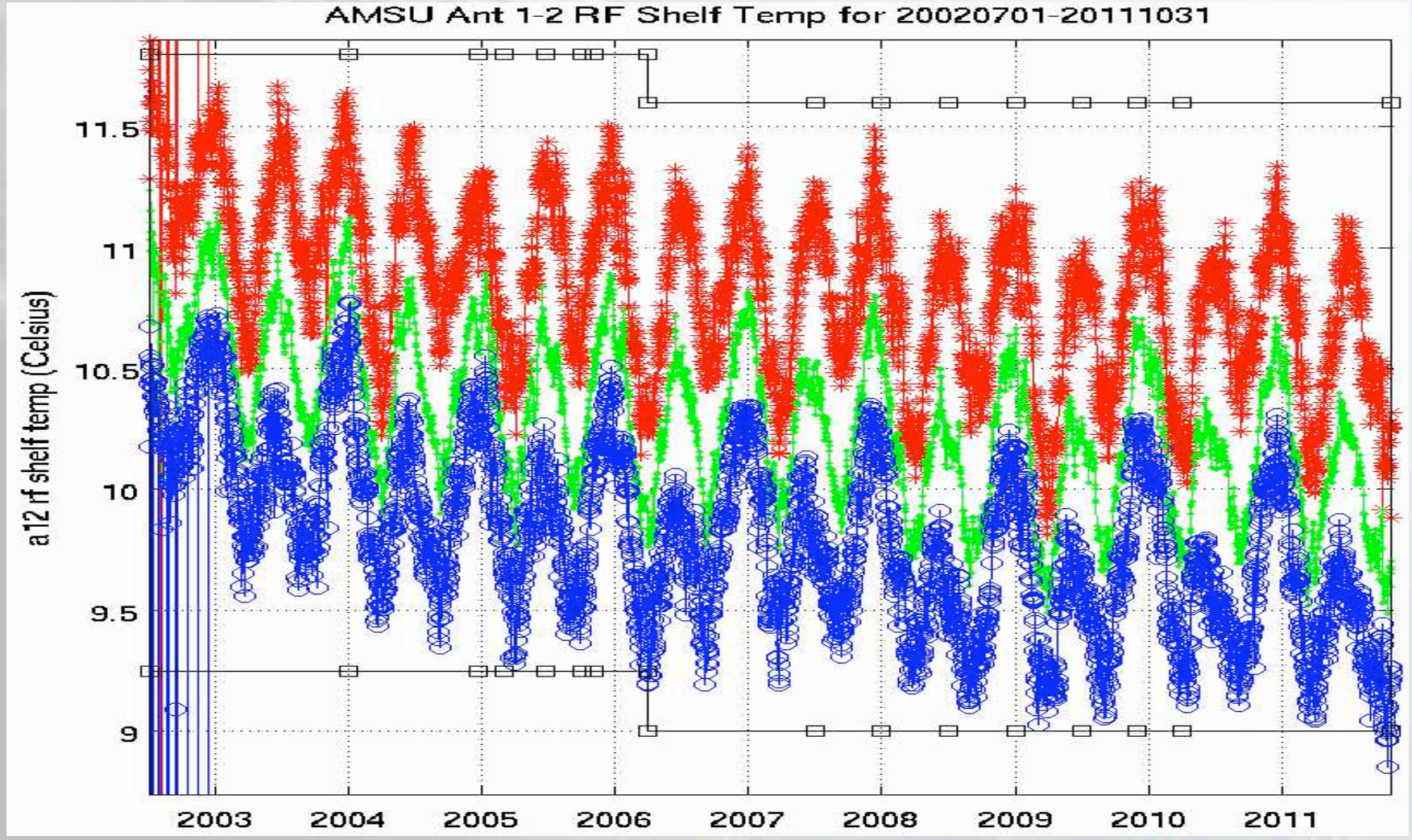
AMSU-A1-2 RF Shelf Temperature

Atmospheric Infrared Sounder



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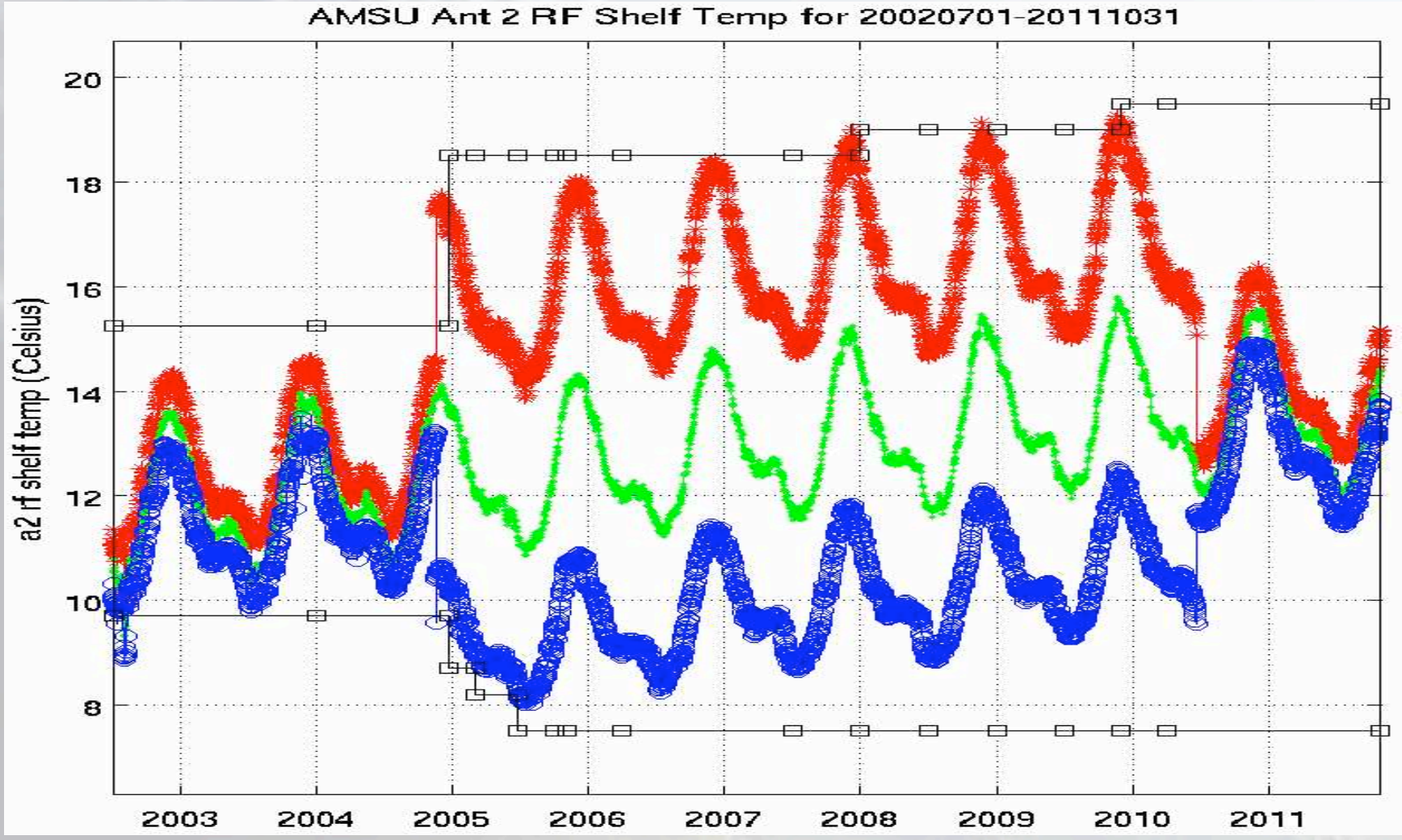
AMSU-A2 RF Shelf Temperature

Atmospheric Infrared Sounder



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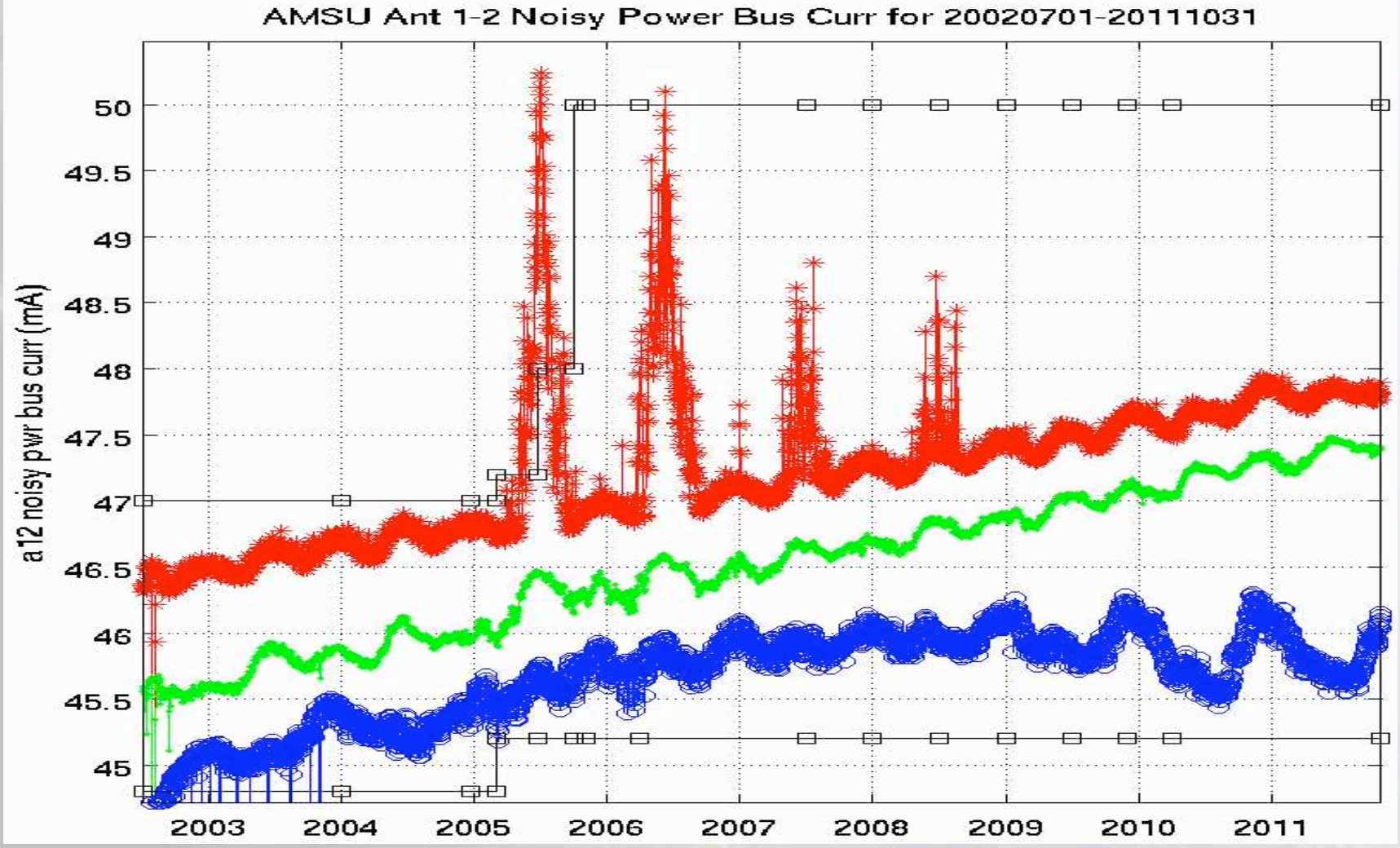
AMSU-A1-2 Noisy Bus Current

Atmospheric Infrared Sounder



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AMSU-A Channel 5 NEΔT

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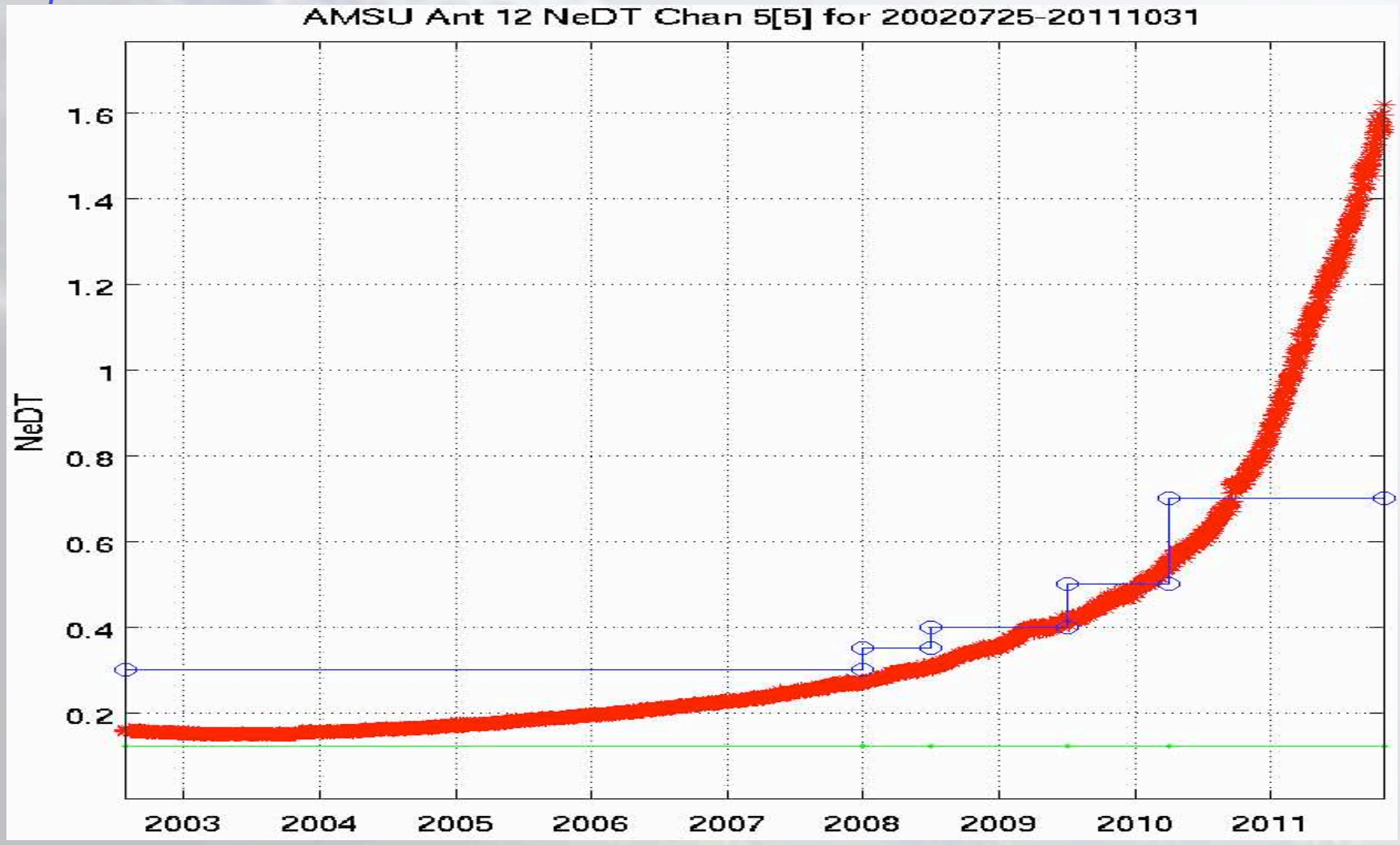


Aqua Status And Anomalies

Aqua Spacecraft Health Status

- **Aqua is in very good health**
- **Several anomalies have occurred over the years**
- **All are considered minor**
- **None have yet impacted operations**
- **They are listed on the next slide**
  - ***More details are in backup slides in this presentation***

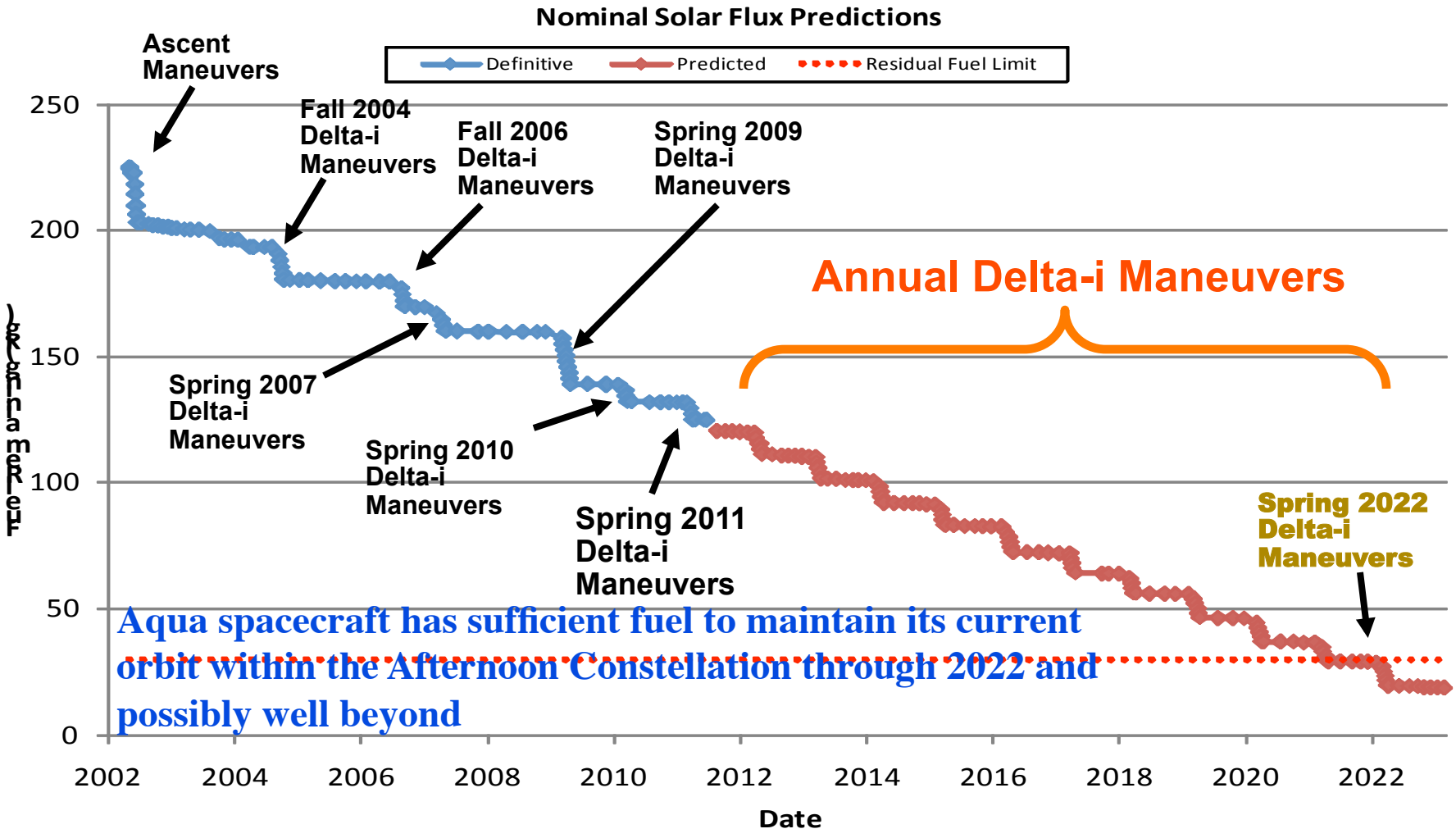
Aqua Spacecraft Anomalies

- **Battery**
  - ***Pressure too high early in mission but now in control***
  - ***Power from one cell behaved erratically for several years but now seems OK***
  - ***Temperature of one cell was high for part of a day***
- **Solar array**
  - ***Potentiometers used for orientation are noisy***
  - ***Thermistor failure on one panel***
- **Formatter Multiplexing Unit/Solid State Recorder (FMU/SSR) hardware timeouts**
- **Computer memory bit errors**
- **Clock rate anomalous drift lasted a few months**

Aqua Fuel Supply

- **Occasional drag make up burns use only a very small amount of fuel**
- **Most fuel usage takes place in orbital inclination adjustment maneuvers, needed to keep Aqua properly aligned with other A-train instruments and to tightly control our 1:30 pm crossing time**
  - ***Three such maneuvers are planned every year, near the vernal equinox***
  - ***A recent estimate of future fuel usage indicates that the hydrazine should last at least until 2022, and possibly longer***

Aqua Fuel Usage: Actual & Predicted (Updated September 2011)



Instrument Anomalies

AIRS anomalies

- **Cooler compressor false overstroke trips in August and October 2002—induced by rad hits in stroke monitoring circuit—each incident caused a loss of 3 days of science data**
- **Scanner halted unexpectedly on November 7, 2004**
  - ***Problem was a single event upset (bit flip) on the scan motor "current mode" register in the ADM***
  - ***Commanding the scanner to move to the OBC and then go into Idle mode cleared the problem***
  - ***14 hours of science data lost***
- **Temperature control CCA suffered an SEU January 9, 2010—17 days of science data lost**

AMSU-A anomalies

- **AMSU-A2 temperature sensors became noisy on November 16 2004, then returned to normal on June 21 2010**
- **Channel 4 failure—declared non-operational as of November 1 2007**
- **Channel 5 degradation continues**
- **Channel 7 never used for L2 (out of spec noise since launch)**

AMSU-A anomalies (continued)

- **AMSU-A1-2 noisy bus current**
  - ***For a period of a few months (centered on the southern hemisphere winter solstice) in 2005, 2006, 2007, and 2008 noisy bus currents rose near the south pole and returned to normal when the spacecraft was not near the pole***
  - ***The problem has been attributed to increased friction in the scanner related to cold temperatures***
  - ***The currents never came close to the yellow limit***

HSB

- **HSB failed on February 5 2003**
  - ***The scanner parked***
  - ***Multiple attempts to restart HSB failed***
- **Cause was traced to an open circuit in the scanner control electronics**

MODIS SRCA Anomaly

- **SpectroRadiometric Calibration Assembly Lamp #3 failed on May 17 2005**
  - ***It was decided that the lamp simply burned out (filament evaporation)***
  - ***The MODIS calibration procedures were changed***
    - Fewer SRCA calibrations per year
    - The brightest setting of the lamps (30 W) cannot be used because it required lamp #3
- **MODIS is otherwise healthy and operating normally**

CERES Fore (FM4) Short Wave Anomaly

- March 30, 2005 bridge balance electronics failure on FM4 unit—short wave channel non-operational
- FM3 was switched to cross-track scanning mode to preserve climate data records
- Some lower-priority CERES science objectives were impacted
- Primary fear is that, if FM3 fails before the follow-on NPOESS missions, there would be a gap in the CERES climate data record
- FM3 and the other two channels on FM4 continue to operate normally
- Root cause believed to be a part failure in the electronics

CERES Fore (FM4) Temperature Anomaly

- On October 20, 2011several temperatures in the CERES Fore instrument dropped sharply and a yellow alarm was set
- The CERES IOT felt that the instrument was not in danger, and instructed the Aqua FOT not to execute the red limit response (putting CERES Fore into survival) even if a red alarm occurred
- CERES Fore was put into safe mode while the CERES team continued to investigate
- CERES Fore remains in safe mode even though the temperatures returned to normal on October 21
- The CERES team is busy with the CERES on NPP, and the Fore instrument on Aqua is now a secondary instrument because of the short wave unit being non-operational since 2005

AMSR-E

- Suffered numerous anomalies (excess commanded torque and excess current in scanner) over the past several years
- On October 4 2011, in response to the largest of these anomalies yet seen, the instrument was commanded to slow from 40 rpm to 4 rpm
- When problems continued even at 4 rpm the antenna was parked
- Unlikely to recover—lubricant failure is probable cause
- Not yet declared dead—AMSR-E team is investigating the possibility of operating at 4 rpm
- Spacecraft jitter was seen in AIRS geolocation data during the spin down, but there was no noticeable impact to science on AIRS or any of the other instruments

New AIRS Gain Table

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Rationale For a New Gain Table

- Exposure to radiation over the life of the mission has caused about 200 channels (out of 2378) to become noisier than specifications
- These channels are not “dead”—just noisier than we would like
- The rate of detectors changing noise behavior has increased in parallel with solar activity
- AIRS guard tests are used to identify whether it is the A detector or B detector or both that are at fault
- If just the A or just the B is noisy, the channel can be restored to in-spec performance by setting the gain of the noisy detector to 0

The New Table

- **A provisional table was transferred from the spacecraft ISC to AIRS for a 24-hour test on Sunday, October 9**
  - ***172 channels had gain changes***
  - ***Over 120 had NeΔT improve significantly***
  - ***Dozens more had non-Gaussian "popping" reduced or completely eliminated ("cold scene noise"***
- **After the test it was agreed that, in some of these channels, the benefit of the reduced noise or reduction of popping was not worth the possible negative effect on climate research due to possible discontinuities in channel properties**
  - ***Another provisional gain table, affecting only 90 channels, is now in preparation***
  - ***It will probably become the operational table within a month***
  - ***The channels dropped from the first provisional list will be studied further, and another new gain table could be developed if warranted***

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AIRS Gain/Circumvention Table Background (1 of 5)

- AIRS detectors are of two different types
  - *PV (photovoltaic) for most channels (Modules 1–10)*
  - *PC (photoconductive) for the longest wavelength channels (Modules 11 & 12)*
- Every PV channel consists of a pair of PV detectors designated A and B
- For each PV channel two types of processing take place on-board—radiation hit circumvention and weighted summation of A and B detectors

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AIRS Gain/Circumvention Table Background (2 of 5)

- Radiation hit circumvention
  - *Depending on the module, either 8 or 16 measurements are made per detector per spectrum—these multiple measurements are referred to as subsamples*
  - *Separately for each detector, each subsample is compared to neighboring (in time) subsamples*
  - *If the difference between the subsample and its neighbors exceeds a threshold, the subsample is replaced by a combination of nearby subsamples*

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AIRS Gain/Circumvention Table Background (3 of 5)

- Weighted summation
  - *The subsamples from the A detector and B detector are separately multiplied by a (possibly different) scale factor (the "gain") and then the two weighted subsamples are added to form a combined A+B subsample*
  - *The combined subsamples are then added to form the sample that is sent to the ground for that channel*

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AIRS Gain/Circumvention Table Background (4 of 5)

- The gain and circumvention thresholds for each detector are stored in the Aqua spacecraft's instrument support controller in three tables
  - *A/B optimum has the "best" values, based on the noise properties of the individual A and B detectors. For each channel individually*
    - Either the A weight = the B weight
    - Or one of the two weights is 0
  - *The A-only table has all B gains set to 0*
  - *The B-only table has all A gains set to 0*

AIRS Gain/Circumvention Table Background (5 of 5)

- The AIRS guard test (run monthly) uploads A-only gains to the instrument, takes some data, then uploads B-only gains and takes more data, and finally restores the optimum table to AIRS to continue routine operations
- Not counting the new table in preparation, the "optimum" table has been changed six times since launch, most recently in November 2003

Table Revision Process Calibration Sequences

- Guard tests are run monthly
- Space view noise tests are run as needed—usually after a new gain table is installed and always after a major change in the instrument configuration
  - *These tests involve staring at space for 20 minutes*
  - *They can be performed with any of the three gain tables operational*
  - *We typically run three of these, once with each of the gain tables*

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Table Revision Process Calibration Sequence Analysis

- The AIRS Instrument Operations Team has Special Test Sequence (STS) analysis software that runs on guard test and space view noise test data
- The STS software produces a recommended gain/ circumvention table

Table Revision Process
STS Output Checking

- The table recommended by the STS software is then gone over by hand
  - *Steve Broberg leads this effort*
  - *Margie Weiler and Evan Manning check Steve's work and sometimes recommend further changes*
- The Cal team, with Tom Pagano and George Aumann present, review the new hand-edited table

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Table Revision Process
Final Table Generation and Upload

- The hand-edited STS software output table is run through another program that formats the table for transfer to the EOC at Goddard
- The Aqua Flight Operations Team (FOT) runs yet another reformatting program, to enable uploading to Aqua
- The Aqua-ready files are tested by the FOT and put into the EOC's configuration management system
- The new files are uploaded to the Aqua ISC

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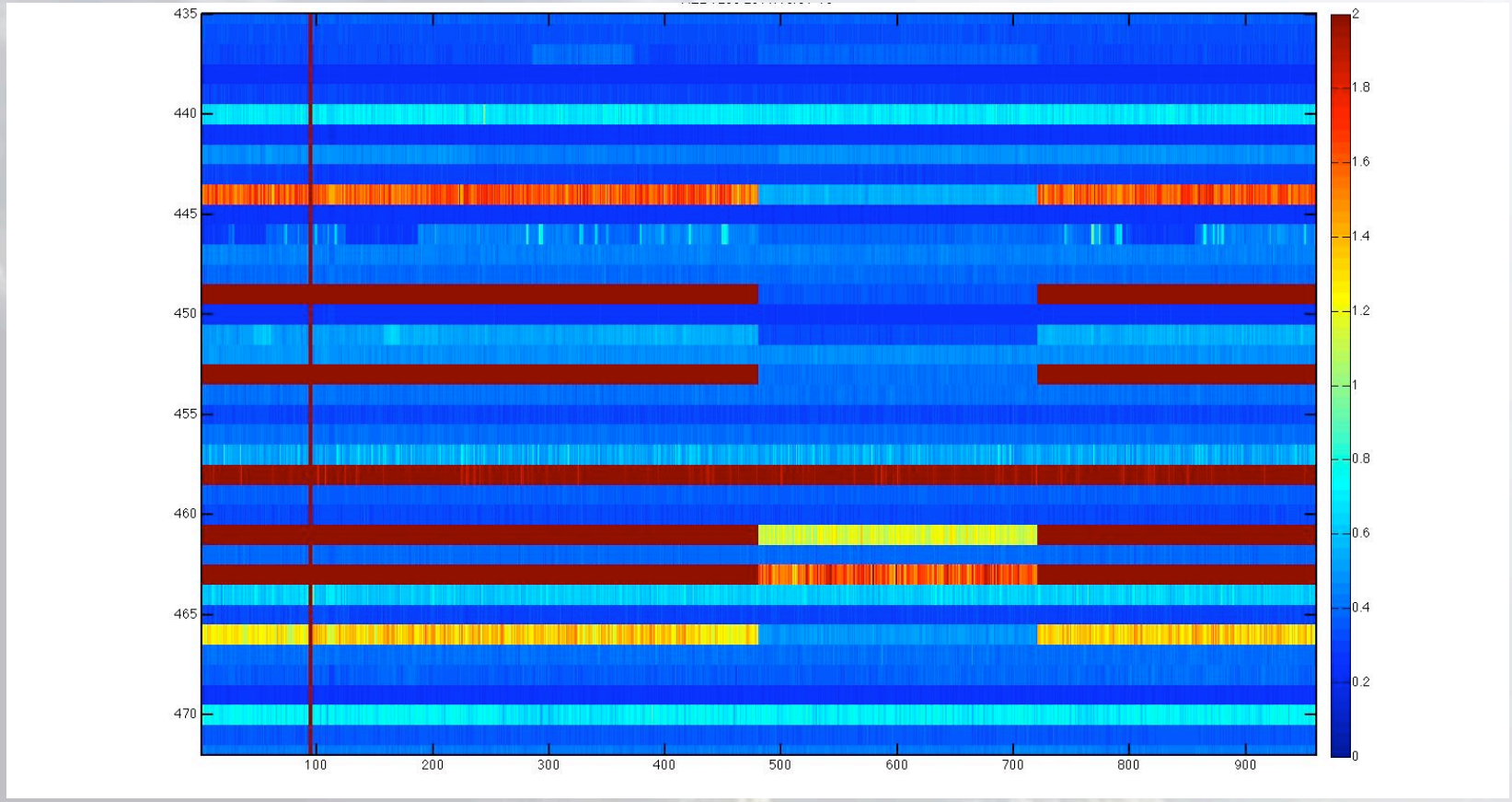
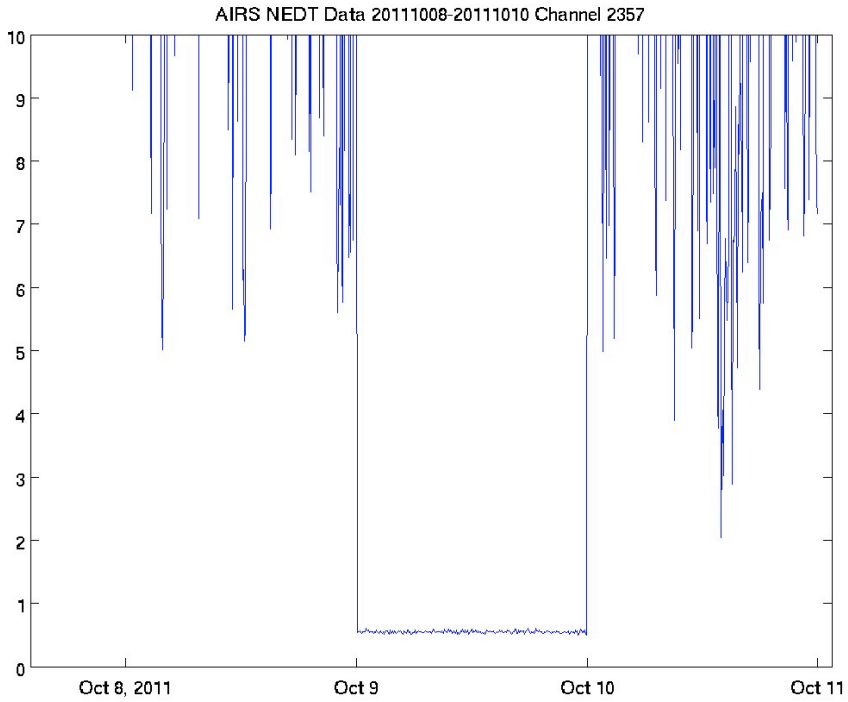
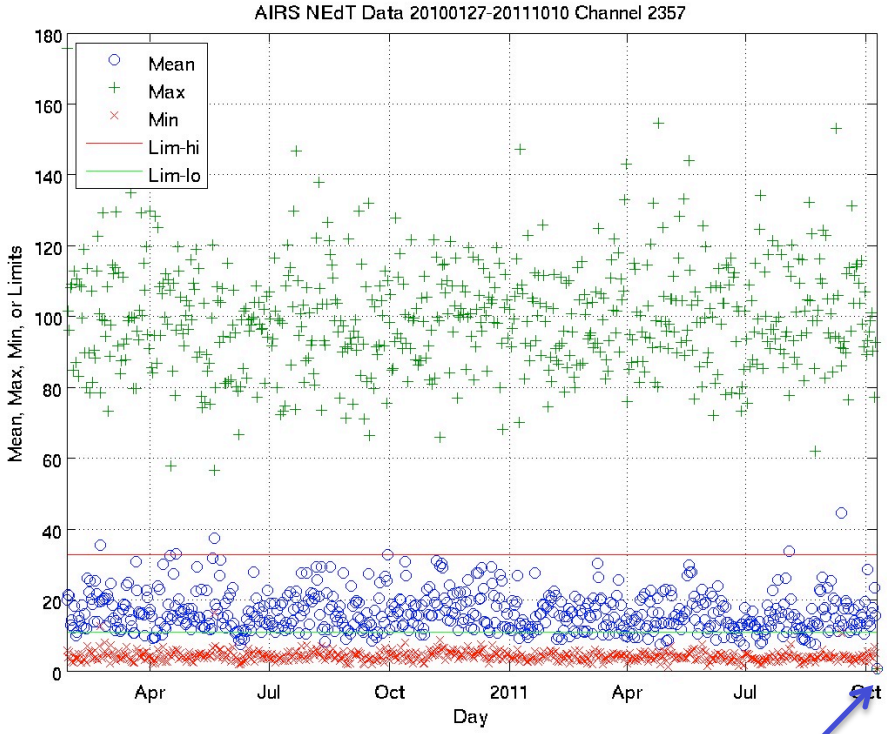
Channel NeΔT October 7–10 2011



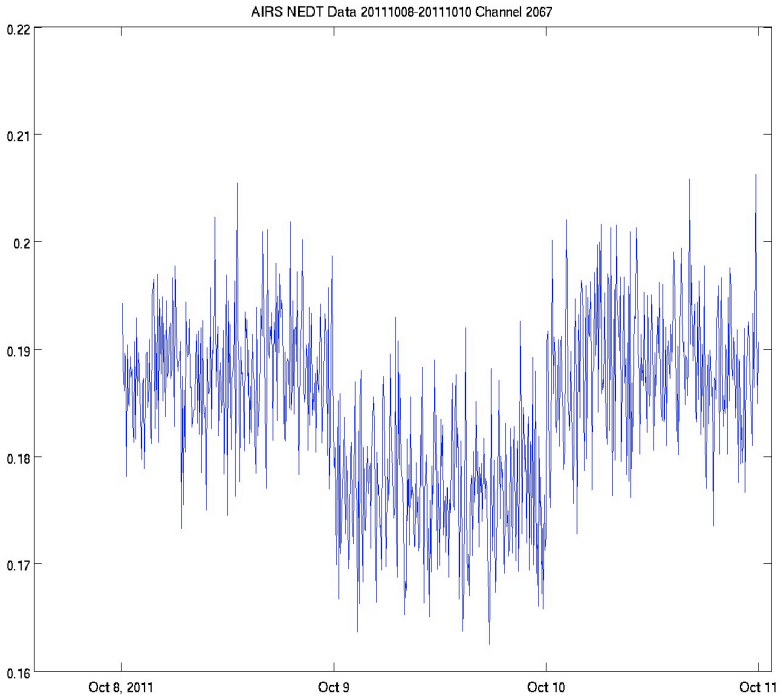
Obvious improvement – Channel 2357, A+B->A

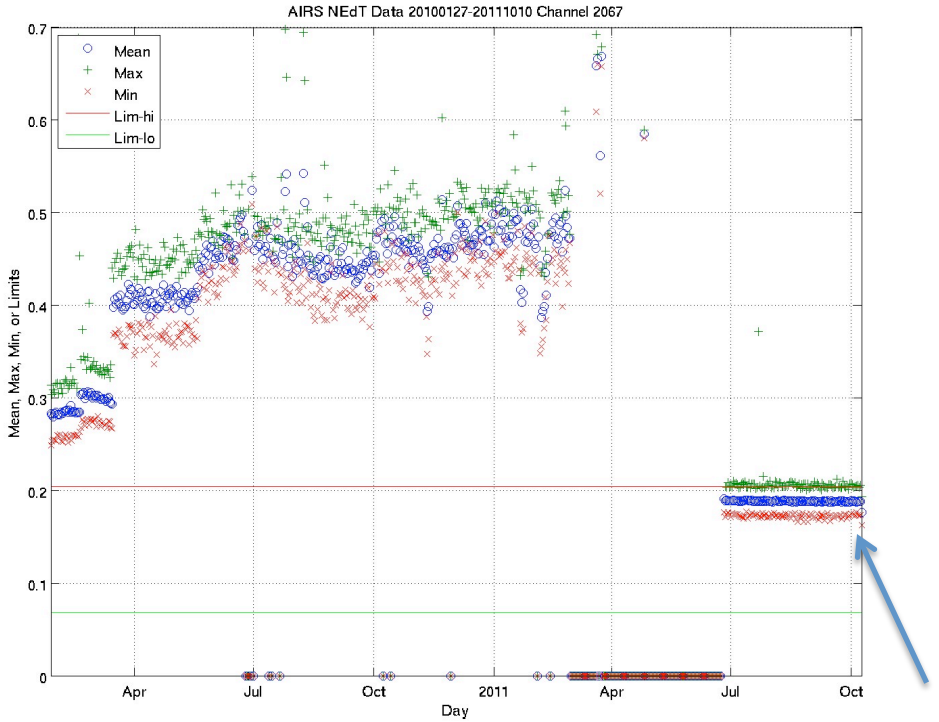




Result: noise changed from >10 K to under 1K.

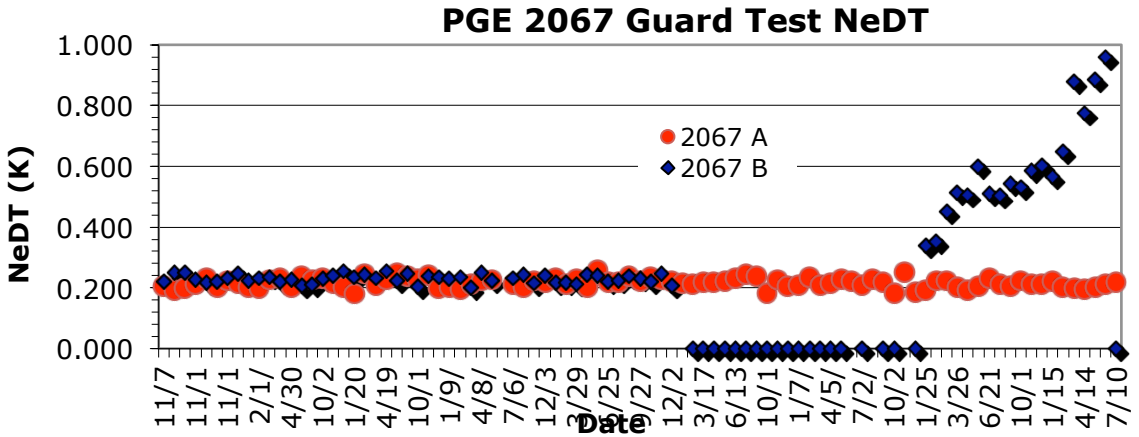
Very slight improvement – Ch 2067



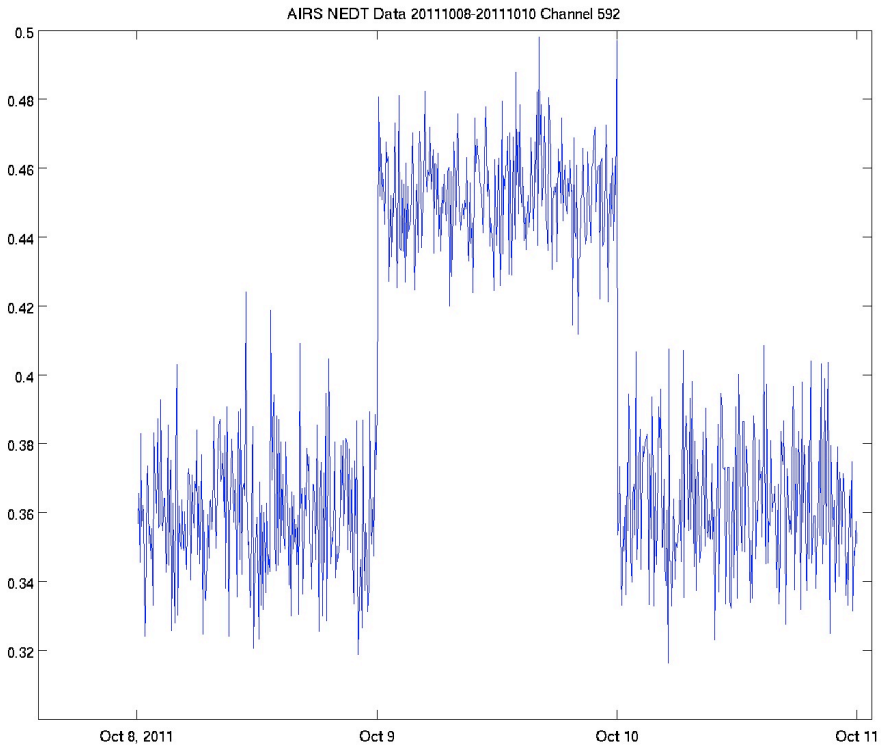


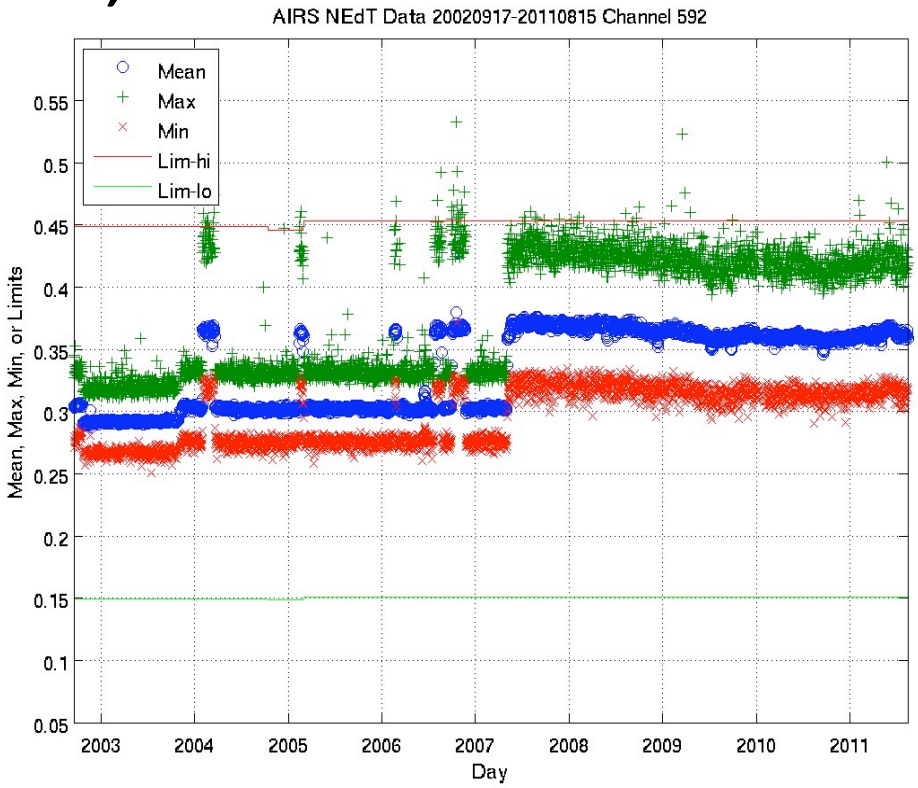
A+B->A. Channel appears to have recovered, but it is not apparent in C2 B data. A side has been stable throughout.

Rationale: improve stability



Slightly worse
Channel 592, A+B -> B

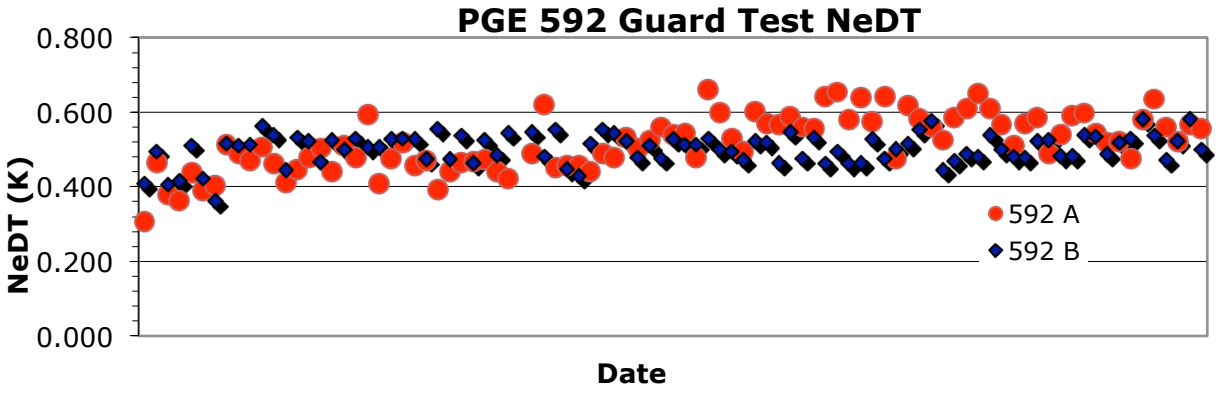




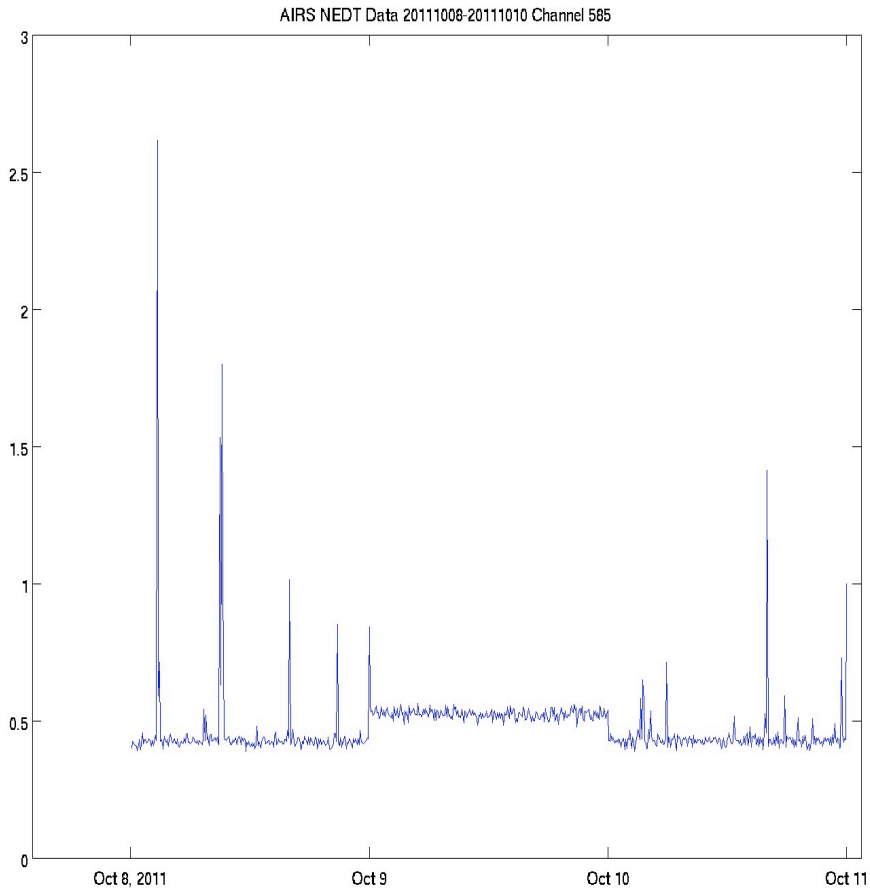
2 states, A non-Gaussian

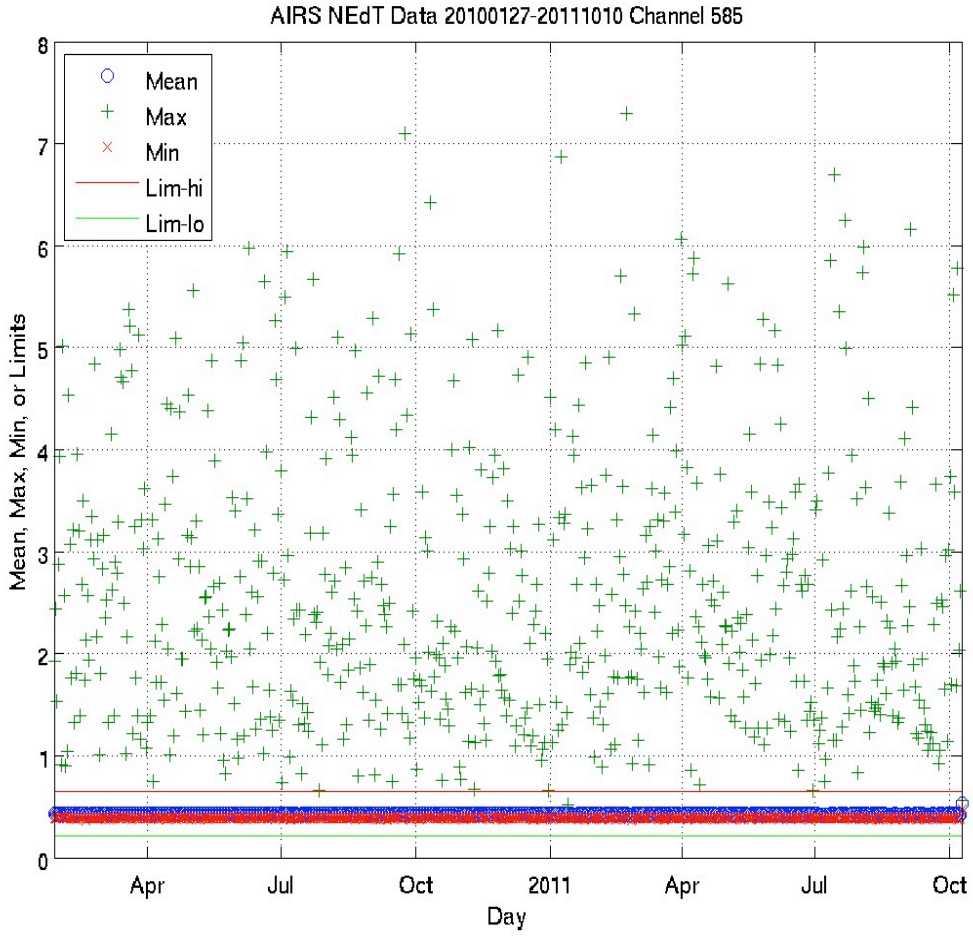
Rationale: improve stability

Result: NEDT 0.36 -> 0.45, no apparent improvement in stability.



Channel 585, A -> B





A has CSN, try B to see if no CSN.

Rationale: eliminate CSN

Spacecraft Anomalies Backup

Battery Pressure

- Shortly before launch, the pressure in the Aqua battery was found to be too high, but launch was not delayed
- The high pressure was attributed to overcharging. The procedures used to charge the battery were changed but as of February 2003 the problem still existed
- Additional charging profile changes were made in December 2005 that corrected the pressure level

Battery power

- **ARE 4A (a battery cell) power problem occurred three times in 2004**
  - ***August 13—power output suddenly dropped but eventually recovered on its own***
  - ***September 9—power output suddenly dropped 15% and stayed down until October 8***
  - ***October 8—power output suddenly recovered then slowly decreased through December 2004***
- **The power output remained stable (at about 90% of the nominal value) until Fall 2009, at which time the output returned to normal!**
- **No cause is known for this strange behavior**

Battery temperature

- **Battery anomaly in BMA-2 cell 4 on September 2, 2005**
  - ***Temperature exceeded yellow high limit and charge/discharge voltage cycle was anomalous***
  - ***Returned to normal on its own***

SADA Potentiometer Fault

- **The Solar Array Drive Assembly (SADA) potentiometers have been degrading ever since launch**
- **Faults have occurred 73 times through the end of August 2011**
  - ***First seen in 2003***
  - ***Most recent event on August 2 2011***
- **The potentiometers are are needed to orient the solar panels at flight software startup and at changes of guidance mode**
- **Alternate methods of controlling the solar array are being investigated—major spacecraft software changes would be required**

Solar Array Thermistor Anomaly

- On August 3, 2009 thermistor #6 on solar array panel #8 failed
- There is a redundant thermistor (#5) that is still working
- If #5 fails, solar panel #8 would have to be taken off-line
- There is enough margin that the loss of just one solar array panel would not impact science operations

FMU-SSR Hardware Timeout Anomalies

- **On three occasions a hardware timeout in the Formatter Multiplexing Unit/Solid State Recorder has interfered with data playback**
  - ***September 22, 2003***
  - ***December 8, 2005***
  - ***August 17, 2006***
- **Spacecraft and ground system software have been modified to minimize the impact of such errors**
- **The root cause is unknown**

FMU/SSR bit error rate

- **FMU/SSR single bit error rate anomalies on April 10, 2006 and February 5, 2010**
  - ***Single bit error rate increased by a factor of 10 to approximately 200 per data dump and have remained at that level***
  - ***No change in double bit error rate***
  - ***No data lost because the hardware can correct single bit errors as long as they do not exceed 680 per data dump***
- **The particular memory modules at fault have been identified**
- **If necessary they can be marked bad, but the procedure to do so would require all instrument science data to cease for several days**

Aqua Computer Memory Bit Flips

- On March 20 and May 10 2006, during passages through the SAA, a memory bit flipped in Aqua memory
- Aqua has several computers on-board and different computers were involved in the two incidents
- The computers have fault protection that catches and automatically corrects single bit errors, so there was no impact on the spacecraft or any instrument

GIRD Clock Frequency Drift Rate Anomaly

- **Aqua has two master clocks**
  - ***GIIS clock is used by MODIS and CERES***
  - ***GIRD clock is used by the spacecraft, AIRS, AMSU-A, and AMSR-E***
- **On September 24, 2004 the GIRD clock frequency began to drift at an abnormally high rate**
- **A number of frequency rate adjustments had restored the frequency to normal by January 13 2005**
- **The actual clock time difference with UTC was never out of spec**
- **The root cause of the problem is unknown**